RECTIFICATION IN DISCHARGE TUBES*

By K. R. CHAUDHARI

ABSTRACT. A detailed study of rectification phenomena in air following the earlier work of Chiplonkar is given. The effect in hydrogen and CO is also discussed.

Recently Mr. Chiplonkar (1939) has made some quantitative investigations of the well-known phenomenon of rectification in discharge tubes. His work was mainly confined to the study of the precise rôle of the electrodes, their relative sizes and the inter-electrode distance in determining the rectification effect. This paper is an extension of Mr. Chiplonkar's work and deals with a detailed study of rectification phenomena in air. The effect in hydrogen and CO has also been partly studied.

EXPERIMENTAL

The discharge tube had an internal diameter of 3.8 cm. and was provided with a cup-like cylindrical anode of aluminium (diameter 1.6 cm. and height 2 cm.), the latter being fitted within a side tube. The cathode was made of an aluminium cylinder 9 mm. thick and with a diameter of 3 cm., and the distance between the anode and the cathode was 16 cm. A hole of 1 mm. diameter was bored coaxially at the centre and it was mounted coaxially by a brass rod of 3 mm. thickness. The brass rod was used only to facilitate the electrical connections. The window of the discharge tube was at a distance of 16 cm. from the cathode and the length of the tube from the window to the conical end was 42 cm. Thus the general form of the tube was similar to that suggested by Thomson (1933).

The electrical circuit employed was the same as that used by Chiplonkar (*loc. cit*). In order to prevent the ascent of mercury vapour from the diffusion pumps and other measuring instruments liquid air traps were employed except in the case of CO, in the investigation of which traps of freezing mixture of ice and $CaCl_2$ were used. The total current passing through the discharge tube was measured by an A.C. Weston milliammeter of the rectifier type, the rectified part of the current being measured by a D.C. Crompton milliammeter connected in series with the first. The current was measured every time immediately after starting the discharge. The ratio of the rectified to the total current is designated here as the rectification ratio and denoted by the symbol ρ. The heating of the tube due to discharge was avoided, as far as possible, by interrupting the discharge for a suitable length of time, between two successive observations. Evacuation of the tube was obtained by means of a set of mercury diffusion pumps of the Waren type backed by a Cenco Hyvac oil pump.

The results for air, hydrogen and CO are shown graphically in Figure 1, where the values of the rectification ratio ρ are plotted against the corresponding values of pressure p. Different sets of observations were taken and the values of the rectification ratio obtained always gave the same type of curve.

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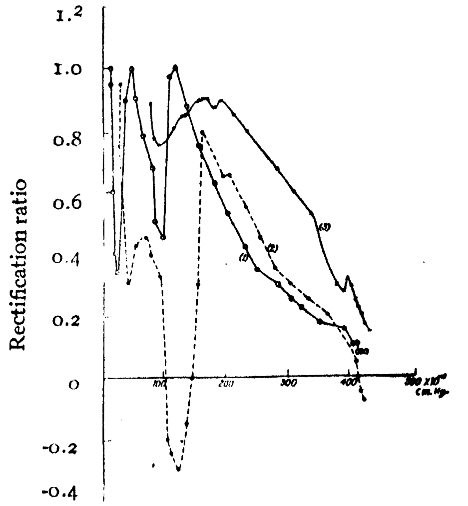


(1) Air (2) Hydrogen (3) Carbonmonoxide

FIG. 1

It can be easily seen from the graphs that the rectification ratio ρ is always positive in the case of air and H_2, while in the case of CO the value of ρ becomes negative at a pressure of 110×10^{-4} cm. of Hg.

It may be noted here that Chiplonkar (*loc. cit.*) has recorded negative values of ρ in the case of air, nitrogen and oxygen at low pressures (about 50×10^{-4} cm. of Hg.). At these low pressures the fourth type of discharge begins and as Thomson remarks, the phenomena under these conditions become very complicated. In general the nature of the discharge is always different with different tubes. The heating of the tubes and the electrification of its walls modify the discharge considerably. The high speed cathode rays ionise the gas and cause changes in the current in the discharge tube.

Again radiation is emitted from some parts of the discharge and especially from the negative glow, which, falling on the metal of the cathode, would by photo-electric effect cause it to emit electrons. There are also several sources of ionisation besides these, *e.g.*, the impact of positive ions against the cathode, moving electrons in dark space, etc.

All these factors contribute to the variations in the rectified current which may lead either to positive or negative values of ρ depending upon the nature of the gas, nature of the electrodes and so on.

In Table I are given the values of the first maxima and minima of the rectification ratio ρ against the corresponding pressures p for different gases. If we look to the densities of these gases, it becomes at once apparent that the first maxima-minima values of ρ appear at higher pressures for gases of lower densities, *e.g.*, the first maximum value of ρ for hydrogen appears at a pressure of 180×10^{-4} cm. of Hg., while those for CO and air appear at 160×10^{-4} cm. of Hg. and 125×10^{-4} cm. of Hg. respectively. This conclusion is supported by the experimental data given by Chiplonkar (*loc. cit.*) also.

It may be mentioned here that the hydrogen curve (Fig. 1) has got subsidiary maxima-minima in the beginning at pressures 398×10^{-4} cm. of Hg. and 391×10^{-4} cm. of Hg. respectively and they are marked with asterisks.

TABLE I

No.	Gas	Density of gas gm. per litre	First Maxima		First Minima		Authors
			Pressure X, 10^{-4} cm. of Hg.	ρ	Pressure X. 10^{-4} cm. of Hg.	ρ	
1	air	1.29	160	0.88	100	0.10	Chiplonkar (1939).
2	oxygen	1.43	125	0.85	80	0.00	,,
3	nitrogen	1.25	180	0.90	100	0.20	,,
4	air	1.29	125	1.00	95	0.40	Author
5	CO	1.25	160	0.80	110	0.30	,,
6	H_2	0.09	180	0.83	170	0.75	,,
7	,,	,,	398*	0.30*	391*	0.25*	,,

VARIATION OF RECTIFICATION WITH TIME

It was found that the rectified current always fell down rapidly within the first half minute and then after an interval of 5 to 15 minutes it became steady. During the study of this phenomenon in the case of air, it was particularly observed that there was a very marked fluctuation around the maxima and minima values of ρ (Fig. 1). Therefore the points around these values were chosen as the most suitable ones for the study of variation of the rectified current, with time. Figure 2 gives a few typical curves showing the fall of the rectified part of the current with the time for which the discharge was passed.

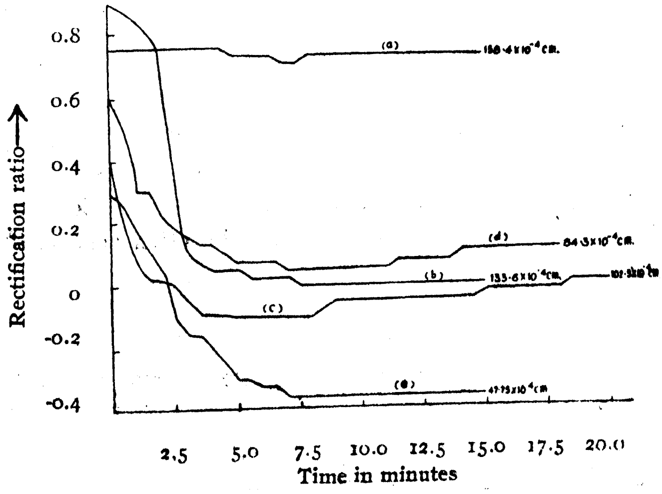
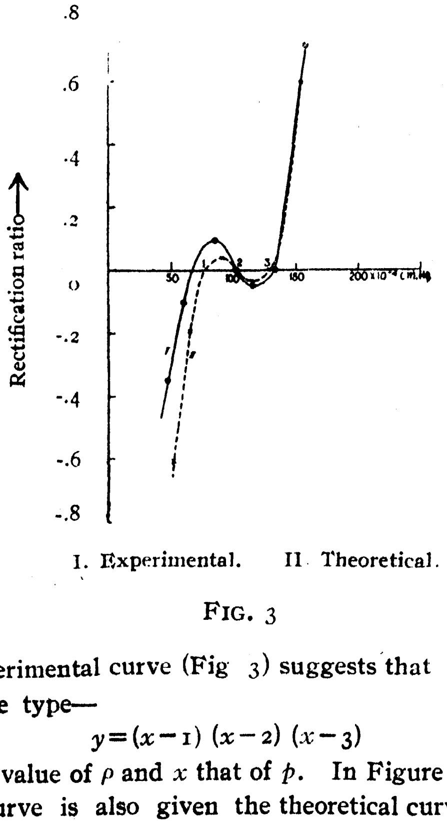


FIG. 2

The uppermost curve '*a*' clearly shows that at a pressure of 158×10^{-4} cm. of Hg. the variation in the rectified current is comparatively very small and the rectification ratio ρ becomes steady at a value of 0.72. At this high value of pressure, the fluctuation is always very small but at low pressures the rectified current goes on falling continuously for about 5 minutes and then becomes fairly steady at a very low value of ρ (see curves *b*, *c*, *d*, *e*—Fig. 2).

It may also be interesting to study the variation of the steady value of ρ with pressure p. Figure 3 is a plot of the steady values of ρ (taken from Fig. 2), against the corresponding values of pressure p.



I. Experimental. II. Theoretical.

FIG. 3

The form of experimental curve (Fig 3) suggests that it can be represented by an equation of the type—

$$y = (x-1)(x-2)(x-3)$$

where y denotes the value of ρ and x that of p. In Figure 3, side by side with the experimental curve is also given the theoretical curve satisfying the above equation. The point corresponding to $x=2$ represents a pressure 102×10^{-4} cm. of Hg. The part of the experimental curve on the right hand side of this point very nearly coincides with the theoretical curve. The other part on the left hand side of the point $x=2$ (Fig. 3) shows an increasing divergence from the theoretical curve.

This divergence can be explained if we consider the heating of the tube due to the continuous discharge. The heating causes a rise of pressure in the discharge tube and consequently the actual pressure existing in the discharge tube for any value of ρ is higher than that indicated on the pressure gauge. Thus the value of ρ obtained experimentally for the different values of pressure as recorded on the pressure gauge really corresponds to higher pressures actually existing in the heated discharge tube. This naturally places the ρ values on the experimental curve above those on the theoretical ones for the corresponding pressures.

EFFECT OF CARBON MONOXIDE ON ELECTRODES

While working with CO, it was observed that the curves obtained for different sets showed wide differences, especially when the interval between the sets was sufficiently long (about a fortnight), observations were therefore repeated with air but here also a wide departure from the original curve (Fig. 1) was noticed. This definitely indicates that the electrodes were polluted by CO. This is in agreement with Oliphant's (Thomson—*loc. cit.*) observations.

SUMMARY

This paper gives a detailed account of some quantitative measurements of the rectification in air in the discharge tubes. The variation of the rectification ratio ρ with pressure in H_2 and CO has also been studied. It is found that the first maxima-minima values of ρ appear at higher pressures for gases of lower densities. While studying the variation of rectification with time, it is observed that the rectified current falls down rapidly at first and then becomes steady at a very low value of ρ.

When steady values of ρ are plotted against the corresponding pressures, a curve is obtained which can be represented by an equation of the form—

$$y=(x-1)\ (x-2)\ (x-3).$$

Lastly the effect of CO on the electrodes is discussed.

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